166-273 SR US REFERENCE SEARCH ROOM
FIP7912 XR 3,270,812

Sept. 6, 1966 R. E. GILCHRIST ETAL 3,270,812
PROGRAMMING
Filed Feb. 16, 1962 3 Sheets-Sheet 1

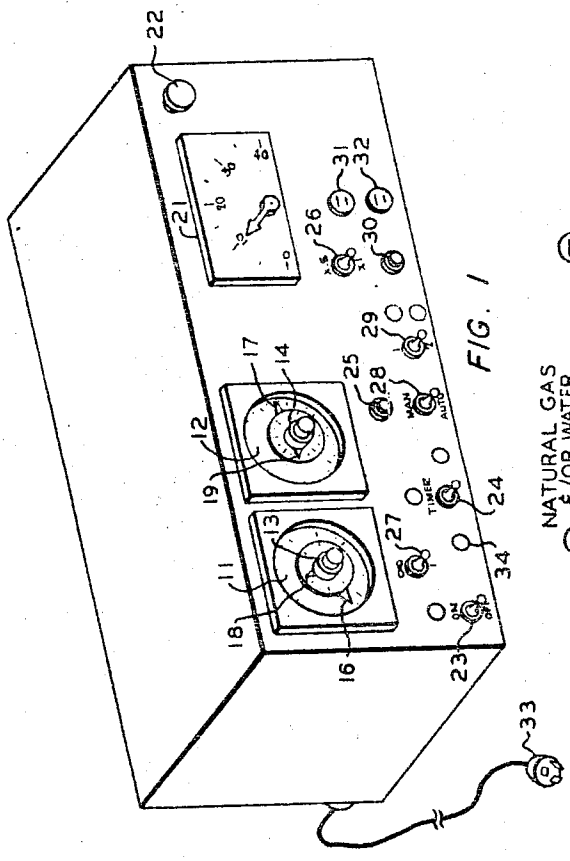


FIG. 1

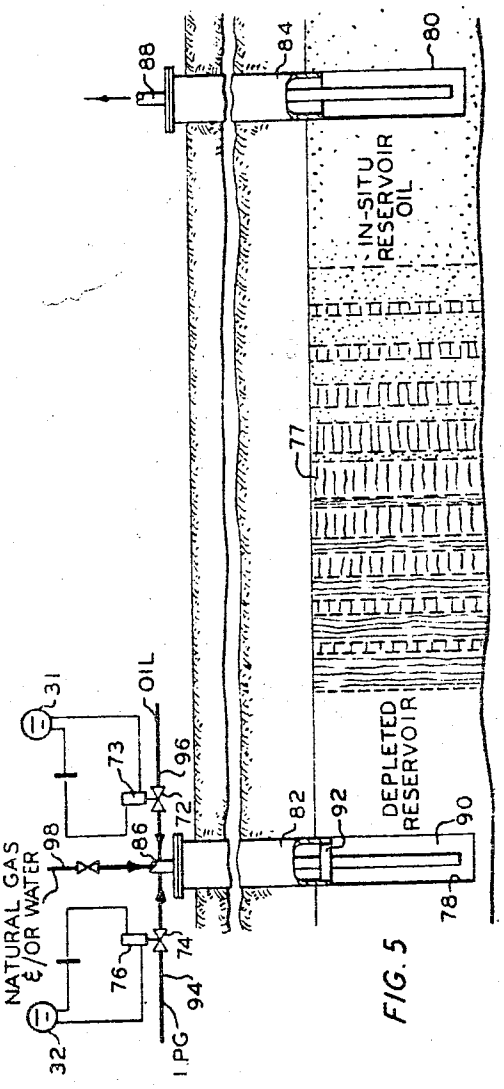


FIG. 5

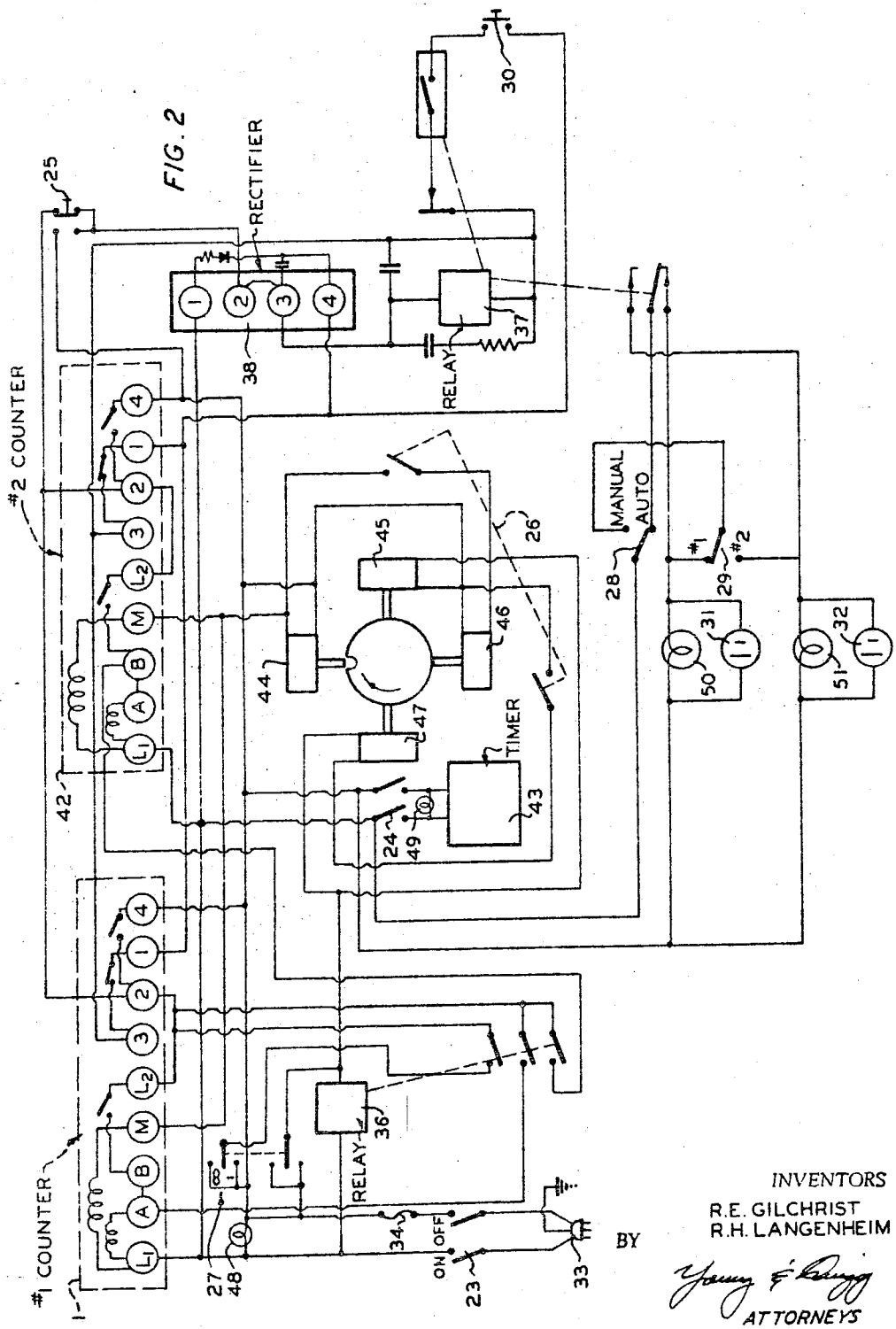
INVENTORS
R.E. GILCHRIST
R.H. LANGENHEIM
BY
ATTORNEYS

Sept. 6, 1966 R. E. GILCHRIST ETAL 3,270,812

PROGRAMMING

Filed Feb. 16, 1962 3 Sheets-Sheet 2

FIG. 2



INVENTORS
R.E. GILCHRIST
R.H. LANGENHEIM

BY

ATTORNEYS

Sept. 6, 1966 R. E. GILCHRIST ETAL 3,270,812

PROGRAMMING

Filed Feb. 16, 1962 3 Sheets-Sheet 3

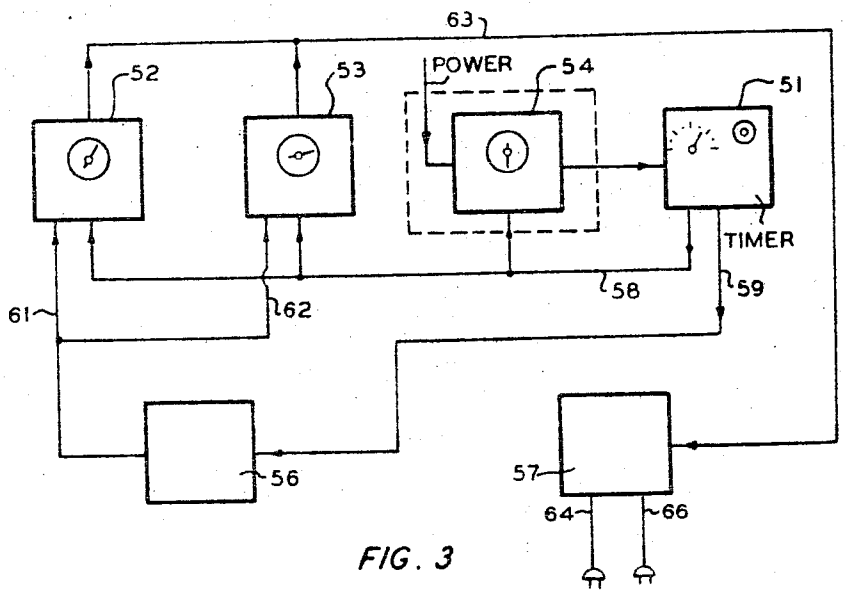


FIG. 3

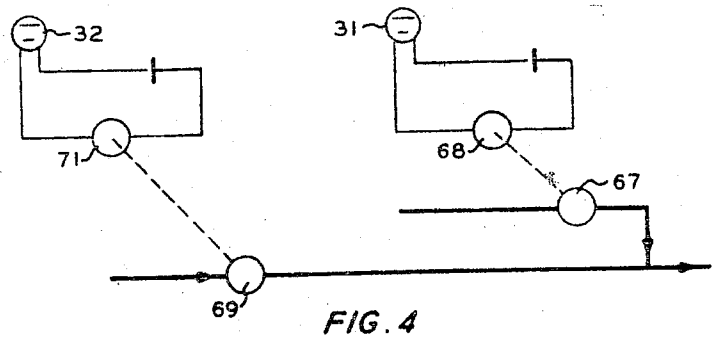


FIG. 4

INVENTORS
R. E. GILCHRIST
R. H. LANGENHEIM

BY

ATTORNEYS

United States Patent Office

3,270,812

Patented Sept. 6, 1966

3,270,812

PROGRAMMING

Ralph E. Gilchrist and Richard H. Langenheim, Bartlesville, Okla., assignors to Phillips Petroleum Company, a corporation of Delaware

Filed Feb. 16, 1962, Ser. No. 173,715
4 Claims. (Cl. 166—9)

This invention relates to method and apparatus for programming. In one aspect the invention relates to a pulse-actuated programmer. In another aspect the invention relates to fluid flow programming means comprising means for programming flow-producing or flow-controlling means. In another aspect the invention relates to means for establishing a varying transition zone in miscible flooding. In another aspect the invention relates to a method for programming, utilizing constant interval electrical pulses. In another aspect the invention relates to a method for programming flow of fluid by programming fluid flow-producing or flow-controlling means. In another aspect the invention relates to a method for miscible displacement comprising the establishment of a transition zone by gradually varying from all of a first fluid to all of a second fluid in discrete steps by programming flow of the fluids.

One method for the recovery of oil from underground reservoirs is by miscible fluid displacement. This comprises the injection of a solvent for the fluid to be produced, followed by a drive, for example with natural gas, to displace the solvent. Frequently a slug of the solvent, such as liquefied petroleum gas, is forced through the reservoir by the following natural gas. The efficiency of the displacement can be improved, through reducing the severity of fingering, by establishing a transition zone between the reservoir fluid and the displacing medium by injecting into the formation alternate slugs of the higher viscosity and the lower viscosity materials, thus forming within the formation a transition zone of gradually varying viscosity between the higher and the lower viscosity materials. Such a zone can be created by manually switching the injection flow from one to the other fluids in varying proportions. However, it is desirable to form the transition zone automatically without close manual supervision. We have found that such a zone can be formed automatically by suitable programming of the fluid injection.

An object of this invention is to provide a method for programming.

Another object of this invention is to provide programming apparatus.

Another object of this invention is to provide method and apparatus for automatically forming a transition zone in miscible fluid flooding.

Other aspects, objects and the advantages of our invention are apparent in the written description, the drawing and the claims.

According to our invention, programming is accomplished by generating a plurality of electrical pulses, counting the pulses and alternating a circuit connection once for a first predetermined number of pulses and once for a second predetermined number of pulses. Our programming method is applicable to the control of flow of different fluids by utilizing switching means to switch from one to another of fluid pumps or by switching valves connecting with more than one source of different fluids. Our method of controlling the variation of fluid flow is useful in the preparation of a transition zone between fluids of different viscosity in miscible flooding operations by gradually changing from all of one fluid to all of another fluid in discrete steps.

Also according to our invention there is provided a programmer comprising an electrical pulse generator, and

at least two counters actuated by the pulses from the generator, and which in turn complete an electrical circuit at periods equal for each counter but unequal for the two counters. Our programmer is especially useful in the control of fluid flow by turning on and off a source of power to fluid pumps or by controlling valves connecting with more than one source of different fluids. The apparatus for control of fluid flow can be used in the preparation of a transition zone between fluids of different viscosities in miscible fluid flooding operations.

In the drawing, FIGURE 1 is a diametric view of a programmer apparatus housing illustrating the control and indicator panel.

FIGURE 2 is a schematic circuit diagram of our programmer.

FIGURE 3 is a schematic circuit diagram illustrating the functional relationship between major components of our programmer, and showing the use of a cut-off counter.

FIGURE 4 is a schematic representation of a pair of flow-control means controlled by our programmer.

FIGURE 5 is a schematic elevation, partly in cross section, of our invention embodied in an underground fluid flooding operation.

In the programmer illustrated in FIGURE 1 a pair of counter dials **11** and **12** are provided and adjustment of the counters is made by knobs **13** and **14**, respectively. Counter dials **11** and **12** are calibrated on an outer scale, indicated by pointers **16** and **17**, in multiples of 20, up to 400, and, on inner vernier scales, indicated by points **18** and **19**, in single units up to 20. Each counter therefore can be set for a specific number of pulses between 1 and 400. These counters are of the type which complete a circuit when a pulse is received corresponding with the number of pulses for which the instrument is set and which, at the next succeeding pulse, start the cycle again. For example, if one of the counters is set for 10 pulses, each tenth pulse completes a contact in the counter. These counters are represented schematically in FIGURE 2 by the dashed rectangles bearing the reference numerals **41** and **42**. An impulse generator is provided and its indicator dial is represented by dial **21**. This dial is calibrated in pulse intervals ranging between 1 second and 28 days. The timer is represented schematically in FIGURE 2 by the reference numeral **43**. This timer is controlled by a knob **22** which adjusts the impulse interval and at the same time indicates the interval selected on dial **21**. Two-pole single throw switches are indicated at **23**, **24** and **26**. Switch **23** is the power switch for the programmer. Switch **24** is the on-off switch for timer **43**. Switch **26** is connected in parallel circuits and determines whether the pulse interval is equal to the interval selected on timer **43** or is halved, the circuit being explained with respect to FIGURE 2. Switch **27** is a two-pole, double throw switch adapted for momentary operation in the down position and being stable in the central or off position and in the up position. This switch is used to control the programmer for a single cycle of operation or to permit it to proceed through a number of cycles. Switches **28** and **29** are single-pole, double-throw switches, switch **28** being a selector switch for manual or automatic operation and switch **29** determining which of the control circuits is actuated in the manual position. This switch can also be used to determine which circuit is actuated at the beginning of the automatic sequence. Electrical outlets **31** and **32** are provided for the controlled circuits to be programmed. Push button switches **25** and **30** also are on the face of the housing, switch **25** for manually producing single pulses, to change the outlet energized when on automatic control, for example, and switch **30** to permit relay **37** to return to home position.

As illustrated in FIGURE 2, the complete programmer comprises switches **23**, **24**, **25**, **26**, **27**, **28**, **29** and **30**, elec-

trical outlets 31 and 32, plug 33, fuse 34, relays 36 and 37, rectifier 38, counters 41 and 42, timer 43, switches 44, 45, 46 and 47, and indicator lights 48, 49, 50 and 51.

The letters and numbers in the circles associated with counters 41 and 42 are the designations applied to the terminals of a commercial counter, Type HZ 40A6, contacts A–242, similar to that illustrated in Bulletin 720 of the Eagle Signal Company, Moline, Illinois. Each of these counters includes a clutch coil connected between terminals L1 and A, a count coil connected between terminals L1–M, normally open contacts connected between terminals B–L2 and 2–4, and normally closed contacts connected between terminals 3–1. When the clutch coil is energized the three switches are actuated, that is, the switches between B–L2 and 2–4 are closed and the switch between terminals 3–1 open. This situation remains as long as the clutch coil is energized, until the count coil receives the number of pulses for which the counter is adjusted on the dial, at which time a mechanical release of the contacts, permitting the switches to return to their normal position, is effected.

Timer 43 can be a Type MG–1000 timer made by Gorrell and Gorrell, Westwood, New Jersey. This timer includes a driving motor and a plurality of cam mechanisms which actuate the connected switches at different rates. The cam wheel illustrated is representative of the various cam mechanisms which can be selected by moving the knob 22. Provision is made on this counter for the installation of the switches 44–47. In this particular installation the switches are located for actuation at 90 degree intervals. The switches are normally closed but are held in the open position by the cam wheel until the depression in the cam is reached, at which time the switch returns momentarily to its normally closed position.

Rectifier 38 is a catalog PA–97 rectifier made by Automatic Electric, Northlake, Illinois. Relay 37 in the particular embodiment illustrated in FIGURE 2 is a rotary stepping switch, a series OCS relay, and AE rotary stepping switch, also made by Automatic Electric. This relay steps once for each pulse received from the counter circuits. At each step one of the outlets 31 and 32 is connected to the relay contacts illustrated. This is a schematic representation, being actually the contacts arranged alternately around the stepping switch. Although not normally needed in the operation of the circuit of FIGURE 2, a push button homing switch 30 provides means whereby the stepping switch can be made to return to its home position, internal interrupter contacts being provided to send the necessary pulses. Switch 30 is not required in normal operation when the rotary stepping switch of relay 37 is adapted for continuous operation through more than one revolution and the controlled circuit outlets 31 and 32 are energized alternately. However, when the stepping switch must be returned for each cycle of operation, or when an irregular pattern for energizing the outlets is provided, such a homing switch is necessary. The operation of a homing circuit is well known and is not described here in detail.

In the operation of the programmer illustrated in FIGURE 2, timer 43 is set for a desired pulse interval, counter 41 is set for a first predetermined number of pulses and counter 42 is set for a second predetermined number of pulses. For example, counter 42 is set for ten pulses and counter 41 for nine pulses. Switch 23 is closed to supply power to the unit, and switch 24 closed to start timer 43. Switch 26 is actuated to the desired position which determines the frequency of pulses transmitted to the counters. With the contacts of switch 26 open, switches 44 and 45 are effective in transmitting pulses to the desired parts of the circuit, while switches 46 and 47 are inoperative due to the open circuit. On the other hand, when the contacts are closed all of the switches are operative. Thus, with the contacts of switch 26 closed the number of pulses is two times the number transmitted with the contacts open.

When the apparatus is turned on, the contacts of relay 37 are in position to connect either outlet 31 or outlet 32, and the corresponding pilot light 50 or 51 lights. If it is desired to start the operation on the opposite outlet, either the switch 28 is moved to manual position and the switch 29 moved to the desired outlet, or, if automatic operation is contemplated, the usual case, switch 25 is actuated to transmit one pulse to relay 37, thus switching its contacts to the opposite outlet. Switch 25 provides the pulse by completing the alternating current supply to rectifier 38, thus causing a pulse in the D.C. output through relay 37. If the circuit to rectifier 38 is already closed, switch 25 interrupts the circuit momentarily, but this latter situation normally would not occur in the usual operation of the apparatus. Actuating switch 27 to the momentary closed position, the position marked 1, energizes relay 36 which closes its contacts permitting the application of power to terminals L2, and A of both counters. Supplying power to terminals A energizes the clutch coils, thus moving the switches to the opposite position from that illustrated in the drawing. The closing of the contacts between terminals B–L2 and 2–4 permits power to be supplied continuously to terminals A until both counters count out at the same time. That is, as long as either of the counters has its contacts latched in there is a circuit connection between terminal 4 and terminal 2. The terminals 2 are connected together and each is connected to the corresponding terminal L2. For the counter which has not reached its predetermined number of counts, the contacts between B and L2 also are closed, thus keeping the clutch coil energized.

When either counter has received the predetermined number of pulses through its count coil the contacts between B–L2, 3–1 and 4–2 are released to return to their normal position. This causes a circuit to be completed from terminal 1 to terminal 3, thus completing the circuit from the terminals 3 and 4 of rectifier 38 through relay 37 to actuate this relay to cause it to step one position.

The programmer continues to run and, when either of the switches 45 and 47 is again actuated, relay M is pulsed and the counter is restarted, provided the contacts 4–2 of the other counter are not open because of simultaneous count out of the other counter. When both counters do count out at the same time, power is removed from both counters and the stepping of the rotary relay 37 discontinues because no further pulses are transmitted by the counters.

If switch 27 is placed in the continuous position, marked infinity on the face of the housing, the same sequence is followed except that timing out of both counters at the same time does not discontinue the operation since power is maintained to contacts L2 through switch 27. The programmer continues to operate, repeating the program each time it is completed.

In the operation described, with the counters set at 9 and 10, respectively, the sequence of operation is 9–1, 8–2, 7–3, 6–4, 5–5, 4–6, 3–7, 2–8 and 1–9. Other sequences can be obtained. For example, if the counters are set at 10 and 8, the program sequence is 8–2, 6–4, 4–6 and 2–8. The programmer also can be built with additional counters to provide more complicated programs and more than two outlets can be provided to permit programming more than two conditions.

FIGURE 3 is a schematic block diagram of a programmer according to our invention utilizing a cut-off counter in addition to the programming counters. This apparatus comprises timer 51, first and second programming counters 52 and 53, cut-off counter 54, relay 56 and relay 57. Because of the circuits employed, a cut-off counter is not needed in the programmer of FIGURE 2.

In the operation of a programmer illustrated in FIGURE 3, the sequence is similar to the operation of the programmer of FIGURE 2, except that a cut-off counter is utilized. Timer 51 is set for the desired pulse interval,

counter 52 is set for a first predetermined number of pulses and counter 53 is set for a second predetermined number of pulses. For example, counter 52 is set for ten pulses and counter 53 is set for nine pulses. Counter 54 is set for the total number of pulses for which it is desired to permit the apparatus to run. One preferred method of operation is to set counter 54 for the total number of pulses required for one complete program cycle. In the present example, the total cycle is taken as 90 pulses. The power supply is then connected to the apparatus and timer 51 begins to run and send pulses to the counters 52, 53 and 54 through conductor 58. Pulses at the same rate also are transmitted through conductor 59 which actuates relay 56 to send energizing pulses through conductor 61 and 62 to counters 52 and 53. Only one such pulse is needed to start the operation of the counter but they are transmitted continuously so that each counter begins operation on the next pulse after counting out. Each time counter 52 or counter 53 reaches its predetermined number of pulses, a circuit is completed through conductor 63 to send a signal to relay 57. Relay 57 is one which changes connections back and forth between a pair of outlets each time a signal is received. That is, for example, if relay 57 has completed a circuit to outlet 64 the first time a signal is received, on the next signal outlet 64 is disconnected and outlet 66 is connected. Similarly, the next time a signal is received outlet 66 is disconnected and outlet 64 is connected. In the particular apparatus and with the particular settings described, at the ninth pulse counter 53 transmits a signal to the relay 57, thus switching from outlet 64 to outlet 66. At the tenth pulse relay counter 52 transmits a signal to relay 57 to change the connection back to outlet 64. At the eighteenth pulse (2×9) counter 53 transmits a signal which switches to outlet 66. At the twentieth pulse (2×10) counter 52 transmits a signal which changes back to outlet 64. This operation continues until the entire cycle of 90 impulses has been completed, at which time it will be seen that outlet 64 was connected as follows 9 of the first 10 impulses, 8 of the next 10 impulses, 7 of the next 10 impulses, and so on down to 1 of 10 impulses, while outlet 66 was connected through the same series of nine groups of ten pulses each, 1, 2, 3, 4, 5, 6, 7, 8, and 9 pulses. With this apparatus connected with two pumps, one powered through circuit 64 and the other other through circuit 66, the pumps can be programmed to transmit fluids in the same ratios. Similarly, outlets 64 and 66 can be used to control flow valves. When timer 54 counts out, the entire operation stops.

In FIGURE 4 a first flow control means 67 is actuated by electrical means 68 controlled by outlet 31 and a second flow control means 69 is actuated by electrical means 71 controlled by outlet 32. In one embodiment means 67 and 69 are pumps and means 68 and 71 are electrical motors, while in another embodiment means 67 and 69 are valves.

In FIGURE 5 a first valve 72 is actuated by electrical means 73, for example a solenoid, controlled by outlet 31, and valve 74 is actuated by electrical means 76 from outlet 32. FIGURE 5 also illustrates our invention applied to miscible fluid displacement of underground petroleum oil. Oil reservoir 77 is penetrated by an injection well 78 and a production well 80. Wells 78 and 80 are provided with casings 82 and 84, and with tubing strings 86 and 88, respectively. The annulus in well 78 is packed with sand or gravel 90 and a packer 92 is set around tubing 86 and the lower end of the casing. The packing of sand or gravel 90 in the well under tubing string 86 insures mixing of the injected fluids within the reservoir in the space surrounding well 78. The section of tubing 88 below packer 92 can be perforated to provide better distribution of fluids in the gravel. Also, casing 82 can be extended to the bottom of the hole, being perforated below packer 92 before packing the hole.

Lines 94, 96 and 98 connect with tubing 86 and with suitable pumps to provide for injection of LPG, oil and natural gas, respectively.

An illustration of the laminar nature of the transition zone is shown between the depleted reservoir and the oil-rich reservoir intermediate injection well 78 and production well 80. This illustration assumes that the injected constituents of the transition zone remain in their respective positions without mixing, to better demonstrate the size and order of the portions injected. Actually, the portions of oil and LPG first injected through well 78 begin to mix as they are forced deeper into the formation by the later injected portions, so that there is a substantially gradual decrease in viscosity upstream of flow in the reservoir, or toward the injection well.

Reasonable variations and modifications are possible within the scope of our invention which sets forth method and apparatus for programming and method and apparatus for fluid flooding.

We claim:

1. Means for miscible fluid displacement of fluids from an underground reservoir penetrated by an injection well and a production well comprising:
   - a first pump for injecting a first displacing fluid into said injection well; a second pump to inject a second displacing fluid into said injection well;
   - a first driving motor for said first pump;
   - a second driving motor for said second pump;
   - an electrical pulse generator;
   - a switching relay to connect said first motor to a source of electrical energy in a first position of a contact thereof and to connect said second motor to a source of electrical energy in a second position of said contact;
   - a first electro-mechanical switching means to count the pulses generated by said generator and to actuate said switching relay to change the position of said contact once for a first predetermined number of pulses from said generator; and
   - a second electro-mechanical switching means to count said pulses and to actuate said switching relay to change the position of said contact once for a second predetermined number of said pulses.

2. A method for miscible displacement of a fluid from an underground reservoir penetrated by an injection well and a production well comprising the steps of:
   - injecting a first displacement fluid into said injection well;
   - alternately injecting a second displacement fluid;
   - generating a plurality of constant interval electrical pulses;
   - counting said pulses and actuating a switching relay once for a first predetermined number of said pulses to change from one of said displacing fluids to the other; and
   - counting said pulses and actuating said relay once for a second predetermined number of said pulses to change back to said one fluid.

3. Means for miscible fluid displacement of fluids from an underground reservoir penetrated by an injection well and a production well comprising:
   - a first valve to control the injection of a first displacing fluid into said injection well;
   - a second valve to control the injection of a second displacing fluid into said injection well;
   - first electrical actuating means for said first valve;
   - second electrical actuating means for said second valve;
   - an electrical pulse generator to transmit pulses at regular intervals;
   - a switching relay to connect said first actuating means to a source of electrical energy in a first position of a contact thereof and to connect said second electrical actuating means to a source of electrical energy in a second position of said contact;
   - a first electro-mechanical switching means to count the pulses generated by said generator and to actuate

said switching relay to change the position of said contact once for a first predetermined number of said pulses; and

a second electro-mechanical switching means to count said pulses and to actuate said switching relay to change the position of said contact once for a second predetermined number of said pulses.

4. Means for miscible fluid displacement of fluids from an underground reservoir penetrated by an injection well and a production well comprising:

first flow control means for controlling the flow of a first displacing fluid into said injection well;

second flow control means for controlling flow of a second displacing fluid into said injection well;

first electrical actuating means for said first flow control means;

second electrical actuating means for said second flow control means;

an electrical pulse generator to transmit pulses at regular intervals;

a switching relay to connect said first electrical actuating means to a source of electrical energy in a first position of a contact thereof and to connect said second electrical actuating means to a source of electrical energy in a second position of said contact;

a first electro-mechanical switching means to count the pulses generated by said generator and to actuate said relay to change the position of said contact

once for a first predetermined number of pulses from said generator; and

a second electro-mechanical switching means to count said pulses and to actuate said relay to change the position of said contact once for a second predetermined number of said pulses.

References Cited by the Examiner

UNITED STATES PATENTS

2,496,779	2/1950	De Jong	317—141
2,503,901	4/1950	Chace	307—132 X
2,867,277	1/1959	Weinaug et al.	166—9
2,911,156	11/1959	Freeman	137—624.15 X
2,927,637	3/1960	Draper	166—9
2,962,610	11/1960	Husband	137—624.11
2,994,814	8/1961	Griswold	137—624.11
3,030,015	4/1962	Wieslander	137—624.11
3,036,229	5/1962	Kemp et al.	307—141.4 X
3,103,972	9/1963	Parker	166—9
3,198,967	8/1965	Roberts	307—141.4

OTHER REFERENCES

Eagle Signal Company, "HZ" Series Microflex Reset Counter, Bulletin 720, November 1959.

CHARLES E. O'CONNELL, *Primary Examiner.*

NORMAN YUDKOFF, *Examiner.*

C. H. GOLD, D. H. BROWN, *Assistant Examiners.*